

FRDA REPORT 075

CLIMATE CHANGE IN BRITISH COLUMBIA -
IMPLICATIONS FOR THE FOREST SECTOR:
DEVELOPING A FRAMEWORK FOR RESPONSE

COMPILED BY

ESSA*

EDITED BY

D.L. SPITTLEHOUSE** AND D.F.W. POLLARD**

FOREST

RESOURCE

DEVELOPMENT

AGREEMENT

Canada

BC 



FRDA REPORT 075

CLIMATE CHANGE IN BRITISH COLUMBIA -
IMPLICATIONS FOR THE FOREST SECTOR:
DEVELOPING A FRAMEWORK FOR RESPONSE

COMPILED BY
ESSA*

EDITED BY
D.L. SPITTLEHOUSE** AND D.F.W. POLLARD***

*ESSA Environmental and Social Systems Analysts Ltd., 705-808 Nelson St.,
Vancouver, B.C. V6Z 2H2

**British Columbia Ministry of Forests, Victoria, B.C., V8W 3E7

***Forestry Canada, Pacific & Yukon Region, Victoria, B.C., V8Z 1M5

Report on the Climate Change Information Meeting, held at the Faculty
Club, University of British Columbia, Vancouver, B.C. on October 13,
1988, and prepared for Forestry Canada, Pacific and Yukon Region,
Victoria, B.C., V8Z 1M5

Scientific authority: David Winston
Forestry Canada
Victoria, B.C.

This report has been reviewed by Forestry Canada and the Ministry of
Forests and approved for distribution. Approval does not necessarily
signify that the contents reflect the views and policies of these
agencies.

ISSN 0835-0752

Canadian Cataloguing in Publication Data

Climate change information meeting (1988: University of
British Columbia)
Climate change in British Columbia

(FRDA report, ISSN 0835-0752; 075)

On cover: Forest Resource Development Agreement
Meeting held Oct. 13, 1989.
Bibliography: p.
ISBN 0-662-16986-7
Fo29-19/075E

1. Forest microclimatology - British Columbia - Congresses. 2.
Climatic changes - British Columbia - Congresses. 3. Forest ecology -
British Columbia - Congresses. 4. Forest management - British Columbia -
Congresses. I. ESSA Environmental and Social Systems Analysts Ltd. II
Pitttlehouse, David Leslie, 1948 -. III. Pollard, D.F.W. (Douglas
Frederick William), 1940 -. IV. Canada. Forestry Canada. V. Forest
Resource Development Agreement. VI. Title. VII. Series.

0390.6C3C54 1989

634.9'28

C89-092124-5

CLIMATE CHANGE IN BRITISH COLUMBIA -
IMPLICATIONS FOR THE FOREST SECTOR:
DEVELOPING A FRAMEWORK FOR RESPONSE

EXECUTIVE SUMMARY

A meeting to discuss climate change and its implications for research and communications within the forest sector in British Columbia was convened on October 13, 1988, by the University of British Columbia, and cosponsored by Forestry Canada and the B.C. Ministry of Forests. Results of these discussions are presented in this report.

The interests and current activities of the 32 participants were outlined, and are presented in an appendix to the report. The responses indicate that a wide array of pertinent expertise already exists in B.C.

A scoping session, led by ESSA Environmental and Social Systems Analysts Ltd., identified the main elements of the climate change issue in B.C. These elements are the processes of climate change, ecological issues, management and policy issues and communication issues. They were used to establish a general framework for assessment purposes. The session identified a large number of gaps in information and understanding, and indicated directions and priorities for future research.

A second discussion, seeded by a hypothetical scenario calling for recommended management practice and the outline of a 10-year research program, revealed a number of basic needs for the formulation of a satisfactory advisory and research program. Specifically, there is a need for more definite climate scenarios, a clarification of objectives for forestry in Canada under a changing climate, a better understanding of biological requirements and future values of the resource, an appropriate means to enhance public awareness of the issue, and a scheme to ensure the effective use of funds and available research capability.

A major recommendation from the meeting was that a high-profile conference should be organized by interested parties within the next two years. The conference would provide the best available scenarios of climate change for British Columbia, examine the implications for the forest sector, and present options for forest management.

ACKNOWLEDGEMENTS

The Climate Change Information Meeting, which provided the opportunity for discussions reported here, was initiated by Dr. Hamish Kimmins, Faculty of Forestry, University of British Columbia, who was also responsible for local arrangements. Financial support for the meeting and preparation of this report was provided by Forestry Canada and the British Columbia Ministry of Forests under the Canada-British Columbia Forest Resource Development Agreement, Extension and Demonstration Sub-program (1985-1990), and by the Research Branch, British Columbia Ministry of Forests.



TABLE OF CONTENTS

EXECUTIVE SUMMARY	iii
ACKNOWLEDGEMENTS	v
1 INTRODUCTION	1
2 WHAT ARE THE MAJOR ISSUES?	2
2.1 Climate and Physical Issues	2
2.2 Ecological Issues	5
2.3 Management and Policy Issues	6
2.4 Communication Issues	7
3 SOME BASIC INFORMATION NEEDS	8
4 CONCLUSIONS AND RECOMMENDATIONS	10
5 LITERATURE CITED	12

APPENDICES

1 LIST OF PARTICIPANTS	13
2 SUMMARIES OF PARTICIPANTS INTERESTS	14
3. ISSUES BEING ADDRESSED BY PARTICIPANTS	54

1 INTRODUCTION

The emission of radiatively active gases into the atmosphere through human activity will probably cause major climatic changes over the next 50 to 100 years (Bolin et al., 1986). This problem has now been recognized and accepted outside of the scientific community as a major threat to society, e.g. Anon (1988). The potential effects on society are large and we need to determine these effects and appropriate responses. Such assessments have been and are being done in a number of sectors and at various areal scales (e.g. Bolin et al., 1986; Shands and Hoffman, 1987; Wheaton et al 1988; Climate Institute, 1988). Pollard (1987) and others have addressed the issue of climate change and forestry in Canada in general terms.

The B.C. forest industry directly and indirectly is a major contributor to the economy of B.C. Forests also provide a large income to the province through recreational use. They are important for wildlife, fisheries and water resources, and are also complex ecosystems that provide an important genetic reservoir. However, no detailed assessments have been made of the potential effects of climate change on the forests, forest industry and non-timber resources in British Columbia.

The first step towards assessing the effect of climate change on B.C.'s forests is reported here. The Climate Change Information Meeting, convened by Forestry Canada with arrangements made by Dr. H. Kimmins (U.B.C.), was held at the University of British Columbia, Vancouver, on October 13, 1988. It was attended by representatives from federal and provincial government agencies, universities and the forest industry and by private consultants. Appendix 1 contains a list of the 32 participants. Environmental and Social System Analysis Ltd. (ESSA) provided the facilitators for the meeting.

The meeting opened with an introduction and overview of the climate change issue by Dr. Kimmins. Examples of possible effects on forestry were presented using the work reported in Shands and Hoffman (1987). This was followed by reviews of the interests and activities of various agencies and individuals with respect to climate change. Summaries of these presentations are in Appendix 2.

A scoping session, led by ESSA, was used to identify many of the issues involved in the question of climate change and forestry in B.C. The issues were grouped under four headings and are presented in Section 2. The interest and activities of the participants have been classified using this grouping of issues and is presented in Appendix 3. The scoping session was followed by a discussion on addressing the issues previously identified. This was facilitated by considering the question of whether or not we could recommend management practises that took into account future climate change. Although specific recommendations were not obtained, factors that currently impede the development of recommendations were identified. This material is presented in Section 3. Conclusions and recommendations are presented in Section 4.

2 WHAT ARE THE MAJOR ISSUES?

A framework was developed prior to the meeting to help organize the issues which were to be discussed (Figure 1). No changes to the framework were recommended during the discussions, but there was inadequate time to thoroughly consider the implications of the structure. It remains here simply as a vehicle for organizing the notes. The notes within each major section are further segregated by type of issue rather than subject area. No attempt was made to evaluate the relative priority of issues.

2.1 Climate and Physical Issues

Basic processes of climate change

- Understanding processes of climate change.
- Distinguish natural variability from anthropogenically induced climate change.
- Determine the role of fire as a contributor to climate change.
- Determine the role of forestry in the carbon dioxide cycle in terms of deforestation/reforestation.

Issues related to climate scenarios and associated uncertainty

- Need for credible climate scenarios.
- Need an understanding of the uncertainties of climate scenarios.
- What is the time scale of the change?
- Need good prediction of future wind conditions; especially given their role in fires and blowdown.
- Need predictions of the frequency and size of extreme events.

Management issues related to climate change processes

- What can we do to stop or reduce the rate of climate change on a world wide basis?
- Consider possibility of using forests to absorb atmospheric CO₂.
- there is a need to monitor climate on an ongoing basis; especially in the forested regions of the province rather than primarily in the habited regions as is currently done. This requires funding.

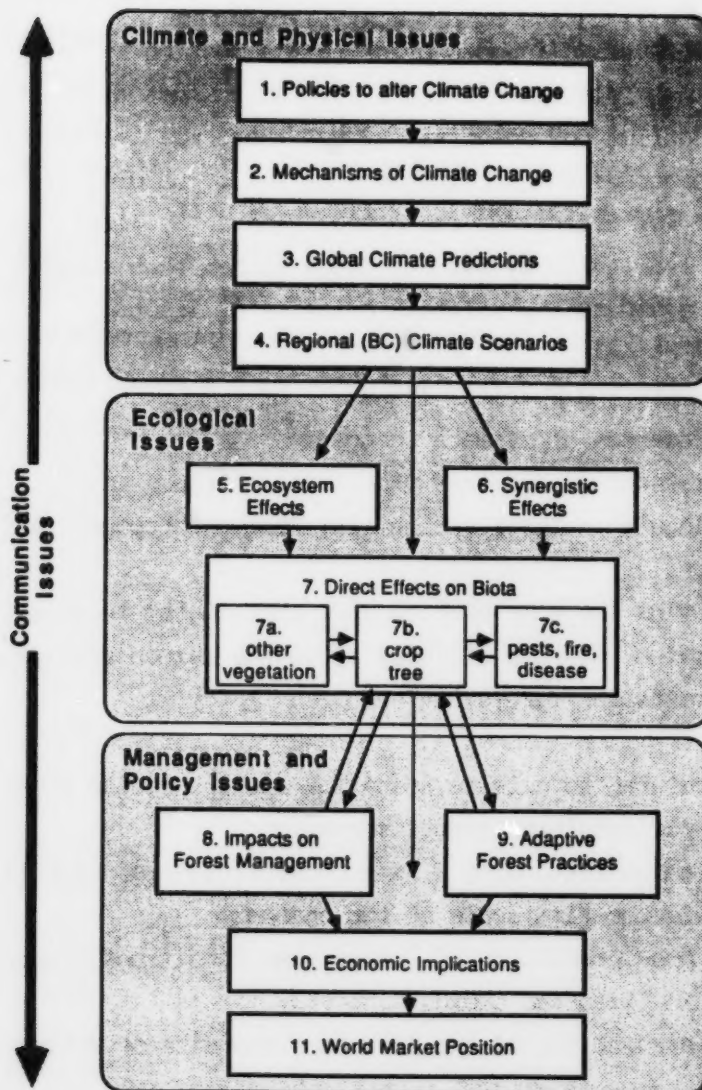


FIGURE 1. Preliminary framework for assessment of the effect of climate change on forestry in B.C.

2.2 Ecological Issues

Basic ecological issues

- A better understanding of the water cycle.
- Need to identify the key climatic factors from the perspective of the ecosystem and vegetation dynamics.
- Why do trees die? We need to understand this in order to determine what options for action are available.
- We need basic information to use as parameters for models.
- Gene conservation.

Understanding and predicting climate change effects

- Understanding the effects of climate change - distinguishing effects caused by climate change from effects caused by normal variation in climate. Determination of the underlying mechanisms.
- Wood quality and productivity, e.g. density, shrinkage, chemistry.
- Learn from the past to predict the future, a role for paleoecology.
- Effect of climate change on weed proliferation and competition.
- Effect of climate on fire patterns.

Ecological uncertainty

- Identify potential sources of surprise, including threshold phenomena such as the chilling requirements.

Interdisciplinary issues

- Need to consider the direct impacts of air pollutants on forest growth
- Need to look at the issue holistically. For example, movement of a species range may cause conflict with other land uses, or place it in areas where soil or topography are unsuitable.
- Need to understand synergistic effects with other natural factors such as insects and disease.
- Need to understand the synergistic effects with other anthropogenic changes.
- Interaction with non-fibre based resources, e.g. wildlife, recreation and water supply.

Applied work

- Develop crop trees suitable for the new climate (genotypes and exotic species).

Integration and coordination of research and management

- Need interdisciplinary teamwork and practical decision-making aids even if they are seen as 'mushy' science.
- Need to consider the implications of changing forest types not only for wood supply, but also for tourism, wildlife and water supply.
- Need to link to other agencies which deal with other natural and social systems.
- Question of how to coordinate at the science level and how to get, or redirect, funding.

2.3 Management and Policy Issues

Do we have adequate information for management?

- Do we have sufficient information at the right level for policy and economic decisions?
- Is the information at the appropriate scale? Concern ranges from site specific to regional or national policy level.
- Are the models being used or designed for planning, forecasting research and data coordination at the appropriate scale, and are they of the appropriate type?

Overall planning.

- We need a broader umbrella, e.g. sustainable development, for dealing with climate change that will link it to other issues.
- Consider the global perspective with respect to wood supply and trade.
- Other effects of climate change, e.g. on food production and the sea level, are likely going to be more pressing; intensive forest management will not likely receive that much attention or funding.
- We need a way of considering the consequences of technological change
 - for adapting the technology of utilization.
 - for incorporating biotechnology

- How much old growth forest do we need? We need to consider genetics, resistance, as well as the area, shape and connectedness of the old growth areas.
- Need to consider the impact of changed yields on the calculation of regional sustained yield and AAC.

Management concerns related to dealing with uncertainty.

- We have to think of management under uncertainty and heterogeneity. There will be mosaics of stands responding differently to change, based in part on genetic variability.
- Determine what we can do right now, given the uncertainty, e.g. intensive short rotations which allow us to respond when needed.
- Develop strategies to reduce risk for the resource and the economic sector.
- When do we switch our goal from maximizing gain to minimizing losses? What new strategies would this require?
- Public objectives may vary with perceived uncertainty, and this has implications as to how research dollars are spent.

2.4 Communication Issues

- There is a need to convert research information to information useful to policy makers. We need to find out what policy makers want, and we should identify the key climate data they desired.
- Climate change is intrinsically a difficult topic, it is so large and interdisciplinary, that it is difficult to get a grasp on it - and yet there is a need to present this in a 30 second briefing.
- How do we communicate uncertainty to the policy makers and public? What actions should they be expected to take in the face of this uncertainty?
- How do we ensure the correct story appears in the media?
- We need to convince people (both government and industry) to spend dollars to gain an understanding of the economic structure and view the world. This is basic to how we formulate long term policies of adaption.
- We should capitalize on volatile public will NOW, it will shift to some other issue soon.

3. SOME BASIC INFORMATION NEEDS

The discussion was seeded by a hypothetical scenario which asked the group to give substantive recommendations on management practice as soon as possible and to outline a 10 year research program. Although specific recommendations were not obtained in the short discussion, concerns which were seen to impede the development of recommendations were raised. The following comprises an "off the cuff" group view of the basic needs that would have to be satisfied to begin a satisfactory advisory and research program.

Need a climate scenario

Right now it is not clear what the problem is with respect to direction, magnitude and timing. There was a suggestion that we may have to accept the uncertainty and deal with alternative scenarios.

Clarify objective of forestry in Canada

- fiber production;
- minimizing CO₂ production;
- minimize fire risk.

Do we run with existing policies? What happens to our presumption of sustained yield?

Adequacy of current information

Do we have enough information to specify a better management alternative?

- Biological information:

For example can we specify what species are at risk by looking at which ones are currently at the borders of their ecological niches?

- Economic information:

For example can we specify what will be a successful crop tree in the future?

Given all the uncertainty what can we recommend?

Two approaches:

- "Safe-fail" strategy

Management aimed to produce logs in a short rotation (30 years) which could be extended to 60 years if all goes well. This would leave us flexibility with respect to reforestation strategies 30 years from now.

- Diversity

Based on genetic variability of stock (unlike nursery stocks), multiple species, and heterogeneity of management regimes.

Education

Research needs to develop tools for education and demonstration of the various possibilities. There is a need for communication strategies to develop awareness. Is there a way to anticipate policy needs for information? We need to:

- convince people that the climate will change;
- determine the implications for the resources;
- implications need to be translated to economics;
- need for visual aids for communication.

Funding

There is the need to prove the worth of research by developing small programs that generate results. It is also a good idea to have some proposals on the shelf, ready for when funding comes along. Possibly ongoing research programmes could be re-interpreted in the context of climate changes.

Co-ordination

How can researchers and management coordinate?

- possibility of matching funds;
- "where we agree" report.

4. CONCLUSIONS AND RECOMMENDATIONS

Climate change is rapidly asserting itself as a major issue in the public eye. It is characterized by major uncertainties in its expected development, in the impacts, and in the response of humankind. The forest sector is brought into the issue immediately because of the exceptionally long term planning implicit in modern forestry, and because of the obvious interrelationships of climate, forest resources and forestry practices. The possibility of transferring carbon to or from the atmosphere, through land use practices adds to the significance of this issue for the sector.

Clearly, the most urgent requirement is the clarification of the issue in terms appropriate to the forest sector. Uncertainty must be delineated and reduced where ever possible. The workshop identified the definition of climate scenarios as the most basic of needs, followed by a clarification of forest management objectives under those scenarios. But large gaps exist in the information required to address climate change from the standpoints of both biological and management response. It would seem that certain precautionary steps may be prudent in the near future, particularly where a "safe-fail" strategy can be employed. The conservation of genetic resources and continued emphasis on backlog reforestation and short rotation forestry would fit into this category. However, before a broad anticipatory and mitigatory strategy can be developed, there must be an effective means for promoting awareness and understanding of the situation as it is now, and as it is likely to progress, with regard to the resource and the socio-economic benefits derived from it.

The overriding needs are immediately evident. First, the allocation of fiscal and human resources to the task of addressing climate change is very limited. With continuing restraint at all levels of government, this is not expected to change dramatically. Nevertheless, current research programs contain much of relevance to the issue, and their results can provide a sound yet inexpensive foundation of knowledge. Second, and closely related to funding, is the need for a coordinated approach to research management and communication among the various elements of the sector. Cost sharing and consensus of opinion to guide decision makers should be two objectives of participating agencies.

The workshop concluded that work on the above concerns could be initiated through a high profile conference. Aimed at the forest sector, the conference would provide current scenarios of change for British Columbia, and for the first time, would provide a platform for experts in key areas to portray the various implications for forestry and the options open to forest managers. It is therefore recommended that all interested parties co-sponsor the conference, to be held within the next two years, and take immediate steps in necessary arrangements.

5. LITERATURE CITED

- Anon, 1988. Conference Statement, The Changing Atmosphere: Implications for Global Security. Environ. Canada, Ottawa.
- Bolin, B., B.R. Doos, J. Jager and R.A. Warrick (eds.) 1986. The Greenhouse Effect, Climate Change and Ecosystems. Scope 29, John Wiley and Sons, New York.
- Climate Institute. 1988. Second North American Conference on Preparing for Climate Change: A Cooperative Approach. Dec. 6-9, 1988, Washington, D.C.
- Pollard, D.F.W. 1987. Forestry and climate change: Facing uncertainty. E.B. Eddy Distinguished Lecture Series, Faculty of Forestry, Univ. Toronto Press, Univ. Toronto, Toronto Ont. pp. 18-39.
- Shands, W.E. and J.S. Hoffman (eds.). 1987. The Greenhouse Effect, Climate Change, and U.S. Forests. The Conservation Foundation, Washington, D.C.
- Wheaton, E.E., T. Singh, R. Dempster, K.O. Higginbotham, J.P. Thorpe, G.C. van Kosten and J.S. Taylor. 1987. An exploration and assessment of the implications of climatic change for the boreal forest and forestry economics of the Prairie provinces and Northwest Territories: Phase One. Sask. Res. Council. Tech. Rep. 211, Saskatoon, Sask.

APPENDIX 1. LIST OF PARTICIPANTS

<u>NAME</u>	<u>AFFILIATION</u>	<u>TELEPHONE NO.</u>
Mike Apps	Forestry Canada, Edmonton	435-7305
David Bernard	ESSA, Vancouver	689-2912
Pille Bunnell	ESSA, Vancouver	689-2912
Edith Camm	UBC - Botany/For. Sci., Vancouver	228-5223
Chris Chanway	UBC - Forest Sciences, Vancouver	228-6019
Rob Guy	UBC - Forest Sciences, Vancouver	228-6023
David Haley	UBC - Faculty of Forests, Vancouver	228-5634
David Handley	MacMillan Bloedel	755-3429
Richard Hebda	Royal B.C. Museum, Victoria	387-5493
Kirk Johnstone	Atmos. Environ. Service, Vancouver	666-6889
Les Josza	Forintek Canada Corp, Vancouver	224-3221
Hamish Kimmins	UBC - Forest Sciences, Vancouver	228-3549
Werner Kurz	UBC - Forest Sciences, Vancouver	228-6020
Bruce Lawson	Forestry Canada, Victoria	388-0600
Ken Lertzmann	UBC - Resource Ecology, Vancouver	222-1573
John Manville	Forestry Canada, Victoria	388-0600
Art Martell	Canadian Wildlife Service, Delta	946-8546
Gordon McBean	UBC - Geography, Vancouver	228-5940
Tim McDaniels	Ste. 310-2025 W 42nd St. Vancouver	263-9615
Tim Oke	UBC - Geography, Vancouver	228-2900
Doug Pollard	Forestry Canada, Victoria	388-0600
Raj Prasad	Forestry Canada, Victoria	388-0600
Ken Redpath	Canadian Wildlife Service, Delta	946-8546
Jean-Pierre Savard	Can. Wildlife Service, Vancouver	946-8546
Tony Shebbeare	COFI	684-0211
Dick Silversides	Forestry Canada, Victoria	388-0600
Olav Slaymaker	UBC - Geography, Vancouver	228-3246
Dave Spittlehouse	B.C. Min. Forests, Victoria	387-3453
Allan Van Sickle	Forestry Canada, Victoria	388-0600
Gordon Weetman	UBC - Forest Sciences, Vancouver	228-2504
Rick Williams	B.C. Environment, Kelowna	861-7211
Dave Winston	Forestry Canada, Victoria	388-0600

APPENDIX 2. SUMMARIES OF PARTICIPANTS INTERESTS

R.J. Hebda
Royal Museum
Victoria, British Columbia

PALEOCOLOGY AND PLANNING THE FORESTS OF THE FUTURE

Potential climatic change resulting from the "Greenhouse Effect" must be considered in reforestation projects to ensure optimum economic return from future forests. The choice of species or species mix to be replanted should be tolerant and thrive under predicted warmer and drier conditions.

Pollen and macrofossil analysis of bog and lake cores reveal the successes and failures of tree species during 12,000 years of postglacial plant-climate experiments. These ancient experiments hold valuable lessons for the planning of future forests. Cores spanning the warmer and drier climate of 10,000 - 7,000 years ago reveal that coastal forests differed markedly from those of today. For example, Douglas-fir and Sitka spruce were important forest trees on north and west Vancouver Island. Western redcedar played a minor role in forests along much of the coast. Practical use could be made of paleoecological analyses by studying cores adjacent to areas scheduled for replanting to discover which species grew during warmer drier climate. Presumably these species would provide better yields 70-80 years from now than those needing more moisture. Such information might be most valuable in transition zones from one forest type to another where climate changes would affect tree growth most drastically.

Atmospheric Environment Service

**Report to the
Climate Change Information Meeting**

**October 13, 1988
University of British Columbia**

Compiled by

**K. Johnstone
Chief, Scientific Services Division
Atmospheric Environment Service
Pacific Region**

PREAMBLE

Dr. D.K. Dawson, formerly the Pacific and Yukon Region Director General of the Conservation and Protection Service, Environment Canada, has recently been appointed Director General of the Canadian Climate Centre, Atmospheric Environment Service (AES), in Downsview, Ontario. Dr. Dawson has lead responsibility for the AES climate program and AES support to the Canadian Climate Program (CCP).

CANADIAN CLIMATE PROGRAM

The CCP is an inter-departmental and inter-governmental program with the AES as the lead agency. The overall objective of the program is to supply Canadians with the best possible climate information in the most cost efficient manner. The AES maintains a Climate Program Office in Downsview to coordinate, promote and provide Secretariat functions for the CCP.

Organizationally, the CCP consists of the Climate Planning Board, chaired by Dr. K. Hare, and three main advisory committees. These committees deal with Data and Applications, Climate Change Impacts and Climate Research. The Data and Applications committee is chaired by Ms. N. Cutler, Director of the AES Climate Applications Branch in Downsview; the Climate Change Impacts Committee is chaired by Dr. B. Smit, University of Guelph.

ATMOSPHERIC ENVIRONMENT SERVICE

Climate Change Impacts Studies

The AES, as lead agency for the CCP, initiated in 1984 a number of studies of the possible socio-economic impacts of climate warming associated with increasing concentrations of CO₂ and other radiatively active gases in the global atmosphere.

Fifteen major studies, some with multiple phases spreading over two-to-three years, have now been completed. These studies have identified some

of the potential direct impacts on: agriculture, forestry, navigation, power generation, fisheries and, recreation and tourism. The impacts of sea level rises on some coastal communities have also been assessed.

Nearly all of these studies have been carried out under contract by Canadian universities or private sector consultants. One case study experiment - to assess the impacts of climate change on agriculture in Saskatchewan, Canada - was completed as part of a joint project with IIASA/UNEP. In the majority of studies, to ensure inter-comparability, contractors were provided with the GISS and GFDL 2 x CO₂ scenarios.

The AES is communicating the results of these studies to the Canadian public through the Climate Change Digest, a new publication series implemented in 1987. Press releases announcing each issue have attracted considerable media attention.

Interest, on the part of other agencies, is increasing significantly. The Canadian Climate Centre will continue to fund additional impact studies, as recommended by the Impacts Committee and approved by the Climate Planning Board. Current priorities for socio-economic impact studies are: water resources, Canada's Arctic, infrastructure, forestry and policy issues. Actual project selection, however, will be largely based on availability of matching funds or contributions of work in kind from other agencies. The AES and CFS have agreed in principle with a proposed study of the impacts of climate change on a timber supply area in northern British Columbia, but the financing has yet to be worked out.

General Circulation Models

A new version of the Canadian Climate Centre GCM has been finalized. The basic climatology run of the new model has begun in preparation for a doubled CO₂ experiment. After the basic climate run of the atmospheric model coupled to a simple "slab" ocean and thermodynamic ice model, the climate impact simulations will be undertaken. A special North American surface data set is being retained for use in impact assessment studies.

The latest model output scenarios from GISS, GFDL, and OSU are on file on the AES Downsview computer. This allows quick access and summary of GCM predictions for climate impacts work. The access systems are menu driven and allow the user to select any time period (month, season or user defined) and any geographic region in North America. The user can compare present (1 times CO₂) and predicted (2 times CO₂) values for air temperature, wind, precipitation, moisture and surface run-off.

Extreme Events

In order to provide improved information on extreme events, a data base of simulated 30-year daily climate histories for 350 Canadian grid points is being prepared. The database is complete but documentation of the work must be finished.

Pacific Region

Regional initiatives to promote an awareness of climate change and its implications include a December 14, 1988 meeting on the Impacts of Climate Variability and Change on British Columbia. The meeting is intended to brief policy makers and planners from federal and provincial government departments on climate variability and change and engender discussion of the issues and concerns that they identify. A special spring show on climate change is being planned for presentation on the Knowledge Network.

The objective of AES Pacific Region is to promote an awareness of climate change and facilitate the study of related impacts where possible. This includes acting as the Regional contact for information and limited support for researchers studying climate change issues in the Region. The Region does not have adequate resources to directly engage in research work on climate change. Persons interested in obtaining GCM output scenarios or further information on the extreme events data base should contact the Pacific Region Scientific Services Division.

DENDROCLIMATIC RESEARCH AT FORINTEK CANADA CORP.

By L.A. Jozsa

Prepared for "Climate Change and Forestry in B.C."
Meeting of the University of British Columbia
October 13, 1988

Summary

Climate affects tree growth directly through the crown (photosynthesis and respiration) and the root system (water and nutrient uptake). Although the growth history of a tree is recorded in its rings, it is extremely difficult to isolate ring patterns produced by past hot/cold or wet/dry conditions since non-climatic factors (such as tree age, competition, etc.) also affect ring growth. For this reason the traditional subjects of dendroclimatology have been open grown old trees in marginal environments, where multiple regression equations have linked individual tree-ring width and density variables directly to temperature and precipitation records to a highly significant degree. However, for vigorous trees from the forest interior this relationship could not be proven; therefore, a more realistic model of the process by which climatic variation affects tree growth was needed. A water balance model was tested which transformed climate data into data of biological significance. This has greatly improved our ability to model tree growth response in forest-grown Douglas-fir trees. Future work should deal with other species and how different climatic change scenarios will impact on forest productivity and wood quality.

Historical Perspective

The start of dendroclimatic research at Forintek can be traced back to 1970. At a conference on the biology of tree-ring formation, methods of measuring tree rings, methods of analysis, and uses of tree ring data (Smith and Worrall, 1970) a scientist named Marion Parker described his X-ray densitometry and dendrochronology program at the Geological Surveys of Canada, Ottawa (Parker 1970). A research manager in the audience, R.W. Kennedy, recognized a great potential for Parker's X-ray densitometry techniques in wood technology research. As a follow up on his strong intuitive feeling Kennedy asked Parker to scan two coastal Douglas-fir trees. One tree was from an open grown, vigorous 30-year-old stand. The other, a forest grown 500-year-old veteran. Increment cores were taken at breast height from both trees. The cores were X-rayed and an 8-year interval (1960-1967) was scanned by Parker (Figure 1). On the average, the fast-grown young tree had 8.8 mm wide rings and grew about 11 times faster than the old one, whose average ring width was 0.81 mm. Ring widths and percent latewood by width were almost constant from year-to-year and therefore unrelated to climatic variation. However, upon closer examination of the relative height of the peaks, which correspond to yearly maximum latewood densities, the two trees showed remarkably similar rankings in

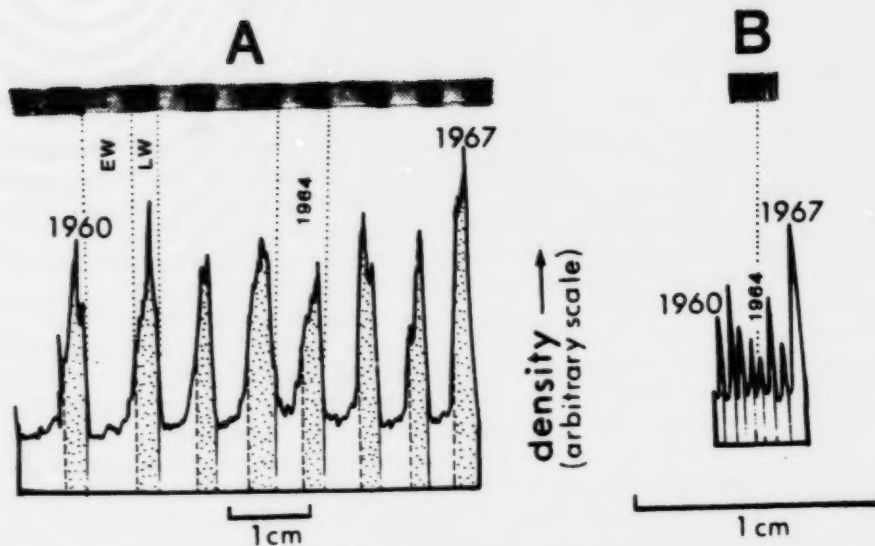


Figure 1. X-ray density scans of two samples of Douglas-fir, representing the 1960 to 1967 annual increments.

- A. 30-year-old open-grown tree;
- B. 500-year-old , overmature tree.

density. The greatest latewood density occurred in 1967, corresponding to the lowest summer rainfall and the highest summer temperatures among the eight years examined, while the lowest maximum latewood density was found in 1964, the year of greatest summer rainfall and coolest temperatures (Kennedy, 1970).

As a direct result of this successful "finger-printing" and deciphering of the climate component of density variation in two vastly different Douglas-firs, Parker was invited by the Western Forest Products Laboratory (Forintek Canada Corp. since 1979) and the U.B.C. Faculty of Forestry, to set up an X-ray densitometry program in Vancouver. The first few years of his work dealt mainly with equipment and techniques development, which included tree-ring data standardization (Parker and Henoch 1971, Parker and Jozsa 1973, Parker and Kennedy 1973, Parker et al. 1973, Smith and Parker 1977, Parker et al. 1980, Parker et al. 1981).

Up to the early 1980s a number of research projects examined the climatic effects on density and ring width variation in several commercially important Canadian softwood species. These included Douglas-fir, white spruce, tamarack, Engelmann spruce and western hemlock. Unfortunately, the ever-present climate signal in tree-ring chronologies could not be deciphered to our satisfaction. Simple linear correlations of ring width and ring density components (such as earlywood width, earlywood density, minimum ring density, maximum ring density, etc.) with air temperature and precipitation records rarely resulted in significant results. Typically, only 30 to 40 percent of the total variance in tree ring series was climate related, yet the proxy evidence of climate was overwhelming. Strong climatic effects were evident through numerous common marker ring-years, highly significant correlations between randomly selected individual cores and site-summary chronologies, and through excellent cross-dating between sites as far as 650 km apart (Jozsa et al. 1984).

In the early 1980s Forintek's dendroclimatic research program underwent a rebirth with the help of Emily Robertson. Her biological training and statistical expertise permitted us to investigate new techniques of tree ring data preparation, in conjunction with principal component analysis, factor analysis, and all possible combinations multiple regression for extracting climatic information from tree rings. Several climatic reconstruction projects were undertaken. Figure 2 illustrates in a flow chart the various key steps of transferring tree-ring data to reconstructions of climate, from tree sampling to transfer function development (Robertson and Jozsa, 1988). At the same time other institutions used, and continue to use, Forintek-derived X-ray densitometric tree ring data to examine the climatic connection (Luckman et al. 1985).

Our attention shifted from climate-sensitive old trees growing under stress on poor sites, to dynamic forest-grown trees; that is, the resource base of the forest products sector. For example, strong climatic effects were detected in a study dealing with fertilization and thinning effects on wood quality (Jozsa et al. 1985). Under the ENFOR program we examined the effect of climatic variability and

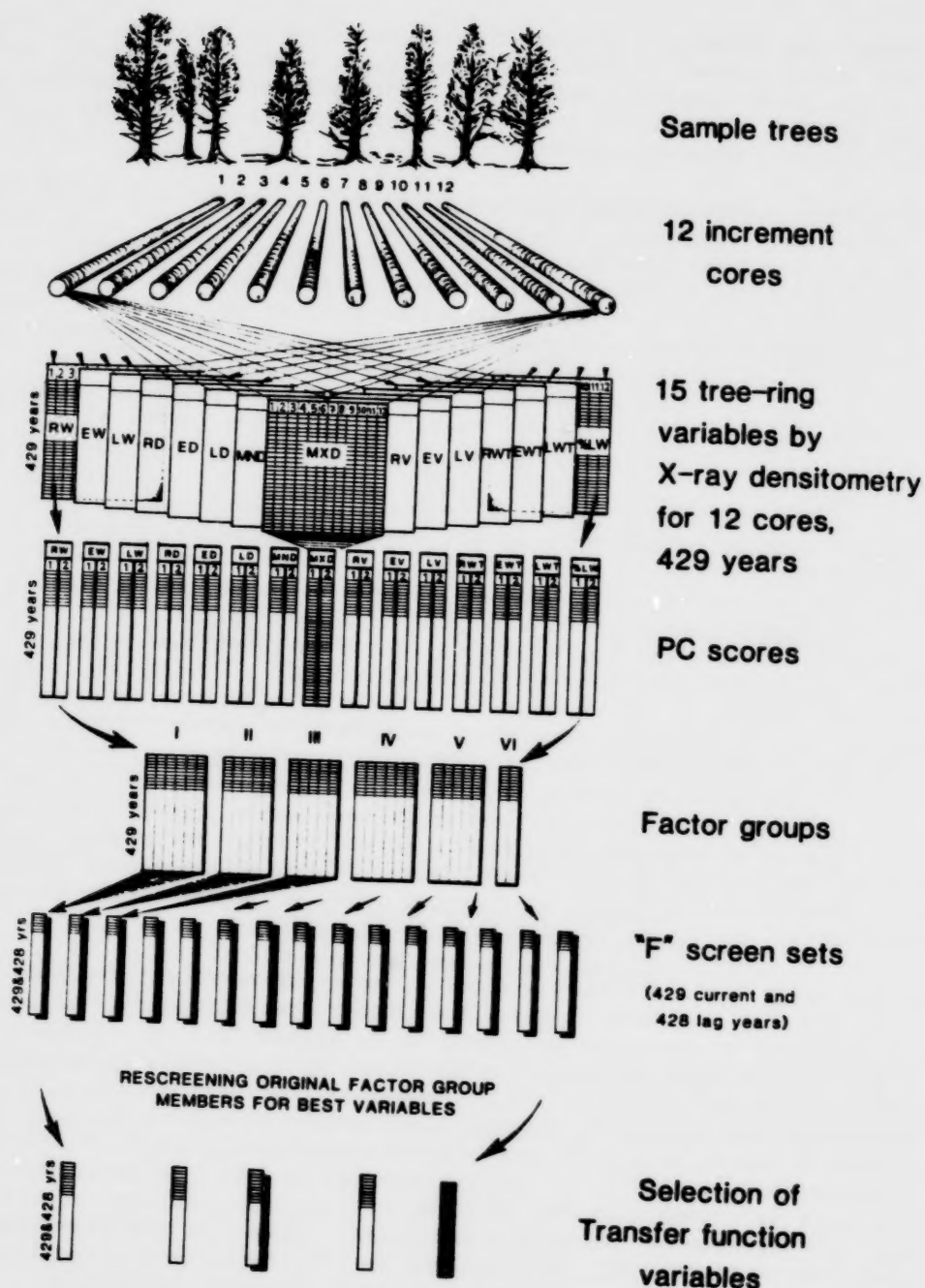


Figure 2. Flow-chart of climatic reconstruction from tree rings: from sampling to transfer function development.

climatic change on wood productivity and on wood quality (Jozsa and Powell 1987, Jozsa 1988). There were some disappointments along the way in developing response function equations for six sites of vigorous 50-year old Douglas-fir on Vancouver Island. The purpose was to compare the linkage between climate variation and wood production from different biogeoclimatic zones. Satisfactory results would have meant that wood productivity could have been calculated from climate data. Although many highly significant response functions were developed for tree ring variables, there were no consistent patterns of predictor variables between different biogeoclimatic zones, or even between stands in the same zone. These results indicated that the method of attempting to link ring variable responses directly to daily temperature and weekly precipitation records was too greatly simplified, and that a more realistic model of the processes by which climate variation affects wood production was needed for vigorous stand-grown Douglas-fir trees (Robertson and Jozsa 1987).

Current and Planned Dendroclimatic Research Program

In 1987 an ad hoc advisory group was formed to examine the results we had obtained and to recommend new possible approaches to evaluating the climate signal in forest grown trees. This group suggested an approach which would tie into the soil moisture deficit work being carried out by David Spittlehouse of the Climatology Branch, B. C. Ministry of Forests and Lands. As a result, we sampled and analyzed 70-year-old Douglas-fir trees on xeric, submesic and subhygric sites. Without exception the trees from the three sites had shown an excellent relationship between soil moisture deficit and tree radial growth. The overall linear regression for 35 years, based on all three sites, accounted for 51 percent of the total variance in ring weight (Figure 3). Thus, for coastal Douglas-fir, approximately 50 percent of the variance in annual ring weight is predictable from annual transpiration stress (Robertson et al. 1988).

The significance of these results lies not so much in the percent variance explained but in the fact that the relationship exists across three different moisture regimes. Therefore, this study clearly demonstrated a linkage of tree productivity with climate (soil moisture deficit). The implications are that, since the study sites span a relatively wide moisture range, the relationship could apply to most coastal Douglas-fir stands; that is, approximately half of the variance in annual ring weight could be predicted on the basis of annual transpiration stress, as calculated by the Spittlehouse model (Spittlehouse et al. 1988). However, it is apparent in Figure 3 that additional site-specific factors account for most of the remaining variability, since the xeric site ring weights remain relatively depressed at all moisture stress levels.

In spite of these exciting results, this was our last climate-related research project at Forintek because of other priorities. Taking stock, we can ask what have we learned, and if funds were made available, what would be our research direction? On the most fundamental level, we know that the climate affects tree growth

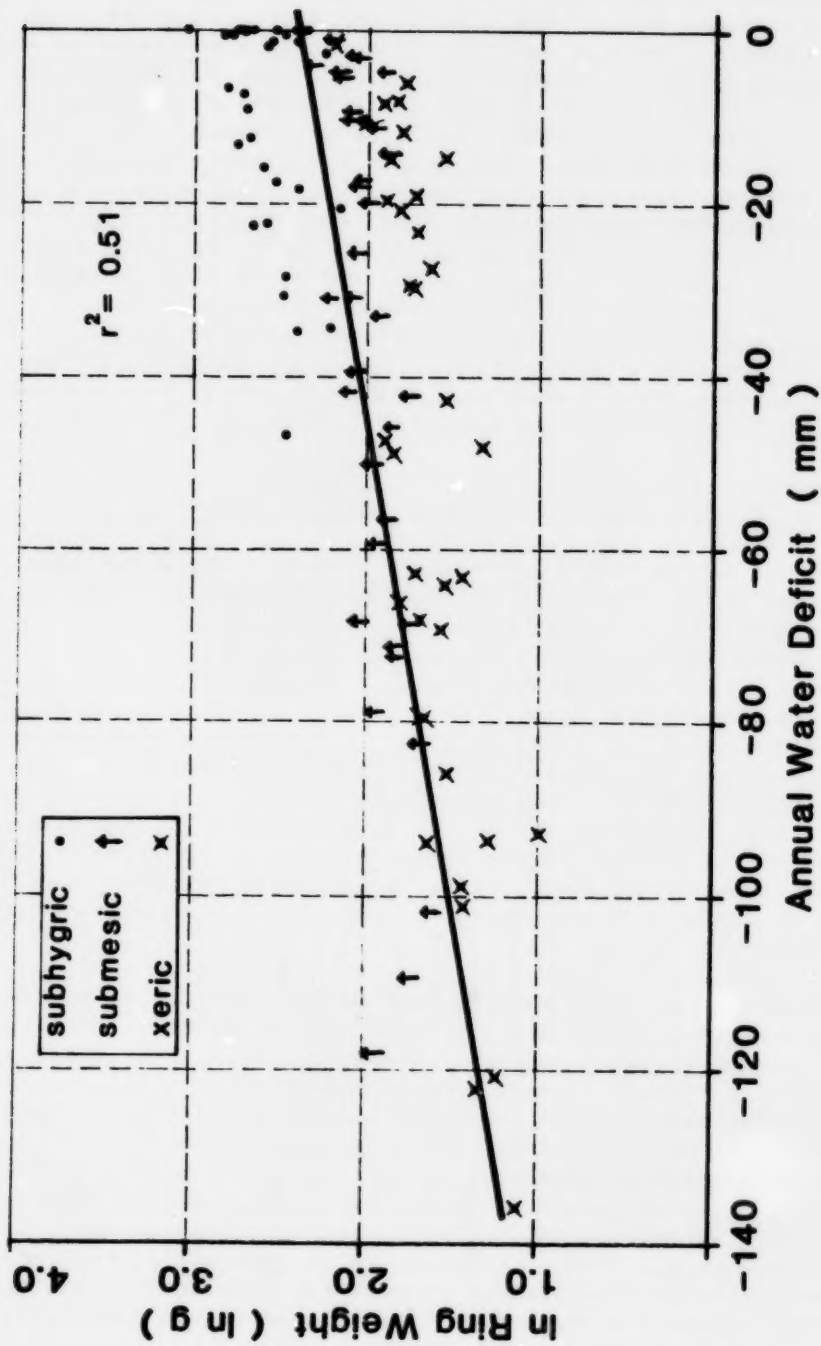


Figure 3. Relationship between ring weight and annual water deficit.

directly through the crown and the root system. Although the growth history of a tree is recorded in its rings we also know that it is extremely difficult to decipher the climate code, especially in vigorous forest-grown trees. The cross-dating example in Figure 1 can be found at most sites but the "hot-cold/wet-dry" content is not as simple for longer intervals, e.g., 50 years, as it was for the eight year period.

We also know that the boreal forest in Canada currently occupies a zone with a mean summer temperature range of only 2°C. Any long-term temperature (and precipitation) change, therefore, even of 0.5°C, would significantly affect the biomass productivity of this zone. Climatic change is of particular significance along the periphery of a species range. Extensive forest die-back has been attributed to climatic variability for several tree species. Lately, the disastrous large forest fires in Northern China, and catastrophic drought in Africa and North America are thought to be the result of changing precipitation patterns. Recently, the British Columbia Ministry of Forests and Lands has directed their attention toward the development of a growth and yield strategy to the year 2000. This has involved intensive discussion between the data producers and the data users. One of the underlying assumptions that seems to have been made in these deliberations is that the climate of the future will be the same as that of the past. There is increasing evidence that this will not be the case. Research has demonstrated the strong influence of climate variations on tree growth, both in terms of annual variation and long-term shift. One of the most important uses of growth and yield information is for evaluating annual allowable cut determinations and long-term production targets. Yield predictions based on past growth history could be grossly in error. If the predictions of climate shifts within the time frame of our next rotation period are correct, it is essential that a mechanism be found to incorporate climatic factors into the development of the yield prediction process. Traditional yield prediction methods are valid only for an unchanging future.

What needs to be done? The overall objective is to develop a technique for predicting the type and amount of resource available for harvest in the future based on climatic variability and change. Specifically, we should follow up on the promising results with Spittlehouse's climate model by examining other Douglas-fir stands and all the commercially important tree species in Canada.

The potential economic impact of the predicted climate shift on forest productivity must be recognized and incorporated into forest planning in Canada. To this end a cooperating research group should be formed with specialists from the following disciplines: wood science, statistics, tree physiology, forest inventory, forest genetics and tree improvement, silviculture, forest climatology and hydrology, micrometeorology and ecology, to develop an overall strategy for this research effort. Support for the effort must then be found.

REFERENCES

- Jozsa, L.A. 1988. The impact of climate change and variability on wood quality. In: Proceedings of Forest Climate '86, Editors: D.C. MacIver, R.B. Street, A. Auclair. Atmospheric Environment Service, Downsview, Ont; 16 p.
- Jozsa, L.A., M.A. Parker, P.A. Bramhall, and S.G. Johnson. 1984. How climate affects tree growth in the boreal forest. Information Report NOR-X-255, NFORC, CFS.
- Jozsa, L.A., P.A. Bramhall, J.A. Cook, and S.G. Johnson. April, 1985. The Effect of Thinning and Fertilization on Wood Quality. Prepared for the Canadian Forestry Service. Forintek Canada Corp. Vancouver, B C. Report No. 02-80-10-016. 42 p.
- Jozsa, L. and J. Powell. 1987. Some climate aspects of biomass productivity of white spruce stemwood. Can. J. For. Res. 17:1075-1079.
- Kennedy, R.W. 1970. An outlook for basic wood anatomy research. Wood and Fiber 2:182-187.
- Luckman, B.H., J.P. Hamilton, L.A. Jozsa, and J. Gray. 1985. Proxy climatic data from tree rings at Lake Louise, Alberta: A preliminary report. Geographic physique et Quaternaire. 39(2):127-140 p.
- Parker, M.L. 1970. Dendrochronological techniques used by the Geological Surveys of Canada. In: Tree-ring analysis with special reference to Northwest America. J. Harry G. Smith and John Worrall, eds. University of British Columbia, Faculty of Forestry, Vancouver, B C. Bulletin No. 7. p. 55-66.
- Parker, M.L., and W.E.S. Hensch. 1971. The use of Engelmann Spruce Latewood Density for Dendrochronological Purposes. Canadian Journal of Forest Research, Vol. 1, No. 2, pp. 90-8.
- Parker, M.L., and L.A. Jozsa. 1973. X-Ray Scanning Machine for Tree-Ring Width and Density Analysis. Wood and Fiber, Vol. 5, No. 3, pp. 192-197.
- Parker, M.L. and R.W. Kennedy. 1973. The Status of Radiation Densitometry for Measurement of Wood Specific Gravity. Proceedings of International Union of Forest Research Organizations (IUFRO), Division 5 meetings in Cape Town and Pretoria, South Africa, September and October, 1973. 17 p.
- Parker, M.L., R.D. Bruce, and L.A. Jozsa. 1980. X-ray densitometry at the WFPL. Technical Report No. 10, Forintek Canada Corp. 18 p.

- Parker, M.L., L.A. Jozsa, Sandra G. Johnson, and Paul A. Bramhall. 1981. Dendrochronological studies on the coasts of James Bay and Hudson Bay. Part II: White spruce annual ring width and density chronologies from Great Whale River (Cri Lake). *Syllogeus*, 1981(33):129-130, 154-188. C.R. Harington, editor.
- Parker, M.L., J. Schoorlemmer, and L.J. Carver. 1973. A computerized Scanning Densitometer for Automatic Recording of Tree-Ring Width and Density Data from X-Ray Negatives. *Wood and Fiber*, Vol. 5, No. 3, pp. 237-248.
- Robertson, E.O., and L.A. Jozsa. March 1987. Estimating Tree Growth From Climate Data for Douglas-fir on Vancouver Island. Prepared for the Canadian Forestry Service. Report No. 87-04-55-12-003. 17 p.
- Robertson, E.O. and L.A. Jozsa, 1988. Climate reconstruction from tree rings at Banff. *Can. J. For. Res.* 18:888-900.
- Robertson, E.O., L.A. Jozsa, and J.E. Richards. 1988. Estimating Douglas-fir wood production from soil and climate data. Prepared for the Canadian Forestry Service. Forintek Canada Corp. Vancouver, B C. Report No. 55-12X-003. 33 p.
- Smith, J.G.H. and M.L. Parker. 1977. A comparison of X-ray densitometry and binocular microscope methods for measuring tree-ring components for Douglas-fir, western hemlock and western red cedar. IUFRO Proj. Group P4.01.05, Instruments, Oregon State University, Corvallis.
- Smith, J.H.G. and J. Worrall. 1970. Tree-ring analysis with special reference to Northwest America. The University of British Columbia, Faculty of Forestry. Bulletin No. 7.
- Spittlehouse, D.L., T.A. Black and D.G. Giles. 1988. Year-to-year variation in water availability and tree growth. In: Proceedings of IUFRO Workshop on Woody Plant Growth in a Changing Physical and Chemical Environment. Editor: Dennis P. Lavender, University of British Columbia. Faculty of Forestry.

DEPARTMENT OF FOREST SCIENCES

PRESENTATION TO CLIMATIC CHANGE INFORMATION MEETING 13TH OCTOBER, 1988

Compiled by

J.P. Kimmins

Interest in climatic change amongst members of the Dept. of Forest Sciences at UBC is relatively recent. This interest was catalyzed by Dr. Denis Lavender, Head of Department, who had worked on the issue at Oregon State University, Corvallis, where he investigated the winter chilling requirements of coastal Douglas-fir. Since coming to UBC he has organized an international meeting (sponsored by the International Union of Forest Research Organizations) on climatic change and forestry, and has done much to raise awareness in the Department about the implications of climate change.

Building on Dr. Lavender's interest, it has been decided that the climate change question will become the framework within which the new WESTFORR group (Western Forest Regeneration Research group) will operate. WESTFORR consists of a core group of researchers (A biochemist (Dr. Edith Camm, Depts. of Forest Science and Botany), a physiologist (Dr. Robert Guy, Dept. of Forest Sciences), an ecophysiologist (Dr. Chris Chanway, Dept. of Forest Sciences), and a regeneration ecologist (Dr. Phil Burton, Dept. of Forest Sciences). Allied with this core group is Hamish Kimmins (ecosystem function (biomass, productivity, nutrient cycling) and ecosystem modelling (FORCYTE, FORCCAST)), Denis Lavender (seedling physiology, regeneration silviculture), Karel Klinka (autecology/silvics, site classification, tree nutrition), Gordon Weetman (silviculture, fertilization), John Worrall (physiology), and various research associates and post-doctoral fellows.

The WESTFORR core group is concerned with a wide variety of issues related to forest regeneration, from the biochemistry and physiology of seedling stress in the nursery and after outplanting, to the competition and other biotic interactions a seedling faces following outplanting. All these topics have relevance to the question of climate change, from changed temperature and moisture stress on seedlings, to altered competitive relationships between crop and non-crop vegetation.

It is envisaged that the climate change-related activities in the Forest Sciences Department will be organized along the following lines:

1. Seedling stress physiology - research to improve our understanding of the response of seedlings to high and low temperature and moisture stress.

2. Winter chilling physiology - research on winter dormancy, the breaking of dormancy relative to climate change, and the implications for growth and growing-season frost damage.
3. Alteration of the geographical location of biogeoclimatic zone and subzone boundaries, and implications for tree species selection and site preparation recommendations.
4. Implications of climate change for nutrient cycling, tree nutrition, tree biomass and productivity.
5. Alteration in patterns of ecological succession and in competition or other forms of interference from non-crop vegetation. Implications of climate change for vegetation management.
6. Design of silvicultural systems that will minimize the management risks associated with climatic change.
7. Ecosystem modelling to provide a forecast (FORCCAST) of the long-term implication of climate change for forest composition, structure and function. FORCCAST (**FOR**estry and **Climatic Change AS**essment**T**) will be developed in conjunction with the completion of the FORCYTE series of model (FORCYTE-12).

In addition to these activities, it is anticipated that the cooperation of our geneticists (Dr. Don Lester, Dr. Oscar Sziklai, Dr. John Worrall), our pathologist (Dr. Bart van der Kamp), our entomologist (Dr. John McLean), our fire scientist (Dr. Michael Feller), and our wildlife specialist (Dr. Fred Bunnell) will be sought to incorporate changes in the risks of fire, insects and diseases, the impacts on wildlife, and genetic aspects of silvicultural responses into our research program.

PREDICTED GLOBAL WARMING AND THE CHILLING REQUIREMENT OF CONIFERS

Denis P. Lavender,
Forest Sciences Dept.
University of British Columbia

Introduction

The role of low temperatures in breaking dormancy was first discovered in 1801, but works did not investigate this phenomenon in woody plants until the early 20th century. Then, although delayed foliation in peaches was reported in Georgia in 1890, low temperatures generally were not related to breaking of dormancy until 1907, when it was recognized that peaches differed in their rest period, and 1920, when Colville investigated the chilling requirements of a number of woody species.

The term "chilling requirement" currently refers to the temperature (commonly around 5°C) and duration of exposure necessary to prepare the apical meristems of temperate perennial plants to resume growth when temperatures become favorable in the spring. Confined largely to plants that are exposed to freezing temperatures during the winter, such a requirement serves to prevent active shoot growth during brief warm spells in winter months, when such growth would be damaged by subsequent low temperatures. (Lavender, 1981)

The horticultural literature of the thirties and forties has a number of references to the chilling requirements of perennial horticultural species and, in fact, the distribution of perennial crop plants in the central valley of California is largely dictated by the number of days of low temperatures occurring at a given location. It is surprising, then, that the discussion of the predicted greenhouse effect has not occasioned concern in the forestry community anywhere in the world with regard to the implication of global warming upon the pattern of winter temperatures necessary to fulfill the chilling requirements of forest trees. Perhaps the reasons are reflected in the data in table 1 - the chilling requirements of several species are relatively short and their distribution may well be affected more strongly by other aspects of climate change, and some species in the table are boreal and even the greatest possible warming will not result in a winter temperature limitation in their present ranges. However, the principal timber species of western North America, Douglas-fir *Pseudotsuga menziesii* (Mirb) Franco) not only has a substantial chilling requirement (Lavender et al, 1986) but has a present range which is predicted to experience significant warming in the coming 50 - 100 years. That Douglas-fir is definitely at risk over much of the more productive portion of its current range is evidenced by the report of (Copes, 1983) which documents the decline of a Douglas-fir seed orchard composed of seedling root stock and mature scion material established in the Monterey Bay region of California a decade ago. The rationale for location of the seed orchard in this area was that there were no natural Douglas-fir to contaminate orchard pollen even though the climate seemed favorable. The reason there were no natural Douglas-fir became evident within three years of the establishment of the orchard when both the understock material and the scions demonstrated a growth habit compatible with that of plants which have received insufficient chilling. The mean temperature of the three coldest winter months in the Monterey Bay area is currently about 11°C. The mean temperature of these same months in much of western Oregon below three hundred meters is 6-7°C.

Although studies in controlled environment chambers may be criticized on the basis that the environments maintained do not accurately represent natural weather patterns, it is virtually impossible to determine the chilling requirements of a plant by exposing it to the natural temperature sequence during winter because: a) the relative efficiencies of temperatures which differ only slightly upon the satisfaction of a given species' chilling requirement may be great, i.e. 10°C. has been shown to be only 50% as effective in satisfying the requirements of *Prunus persica* as 6°C.; b) the internal bud temperature

and not the air temperature is the effective temperature for the chilling requirement and, therefore, sunny days with low air temperatures may not be effective in satisfying the chilling requirement; and c) it is not clear what effect periods of warm temperatures, i.e. 15 - 20° C. may have on the sequence of physiological changes associated with the satisfaction of the chilling requirement.

Controlled environment chamber studies with Douglas-fir (Lavender et al, 1986) demonstrated that this species has a chilling requirement of from 12 to 14 weeks at 5° C. and, further, that this requirement was consistent for a range of seed sources from western Washington and Oregon at both low and high elevations. When a constant 7°C. or 9°C temperature was employed to satisfy the chilling requirements, the growth response of the seedlings in a subsequent favorable environment was delayed significantly with reference to that which occurred after the 5° C. treatment. Long term weather data for a range of stations in western Oregon demonstrate that the mean temperature for the three coldest months of the year at stations below 300 meters is in the range of 5 - 7° C. It is evident, then, if global warming results in an increase of winter temperatures of 5 - 7° C in northern California, Oregon, and Washington as currently predicted, that Douglas-fir will be eliminated from the productive forest stands below 300 m and possibly even higher.

I do not have detailed weather data for British Columbia, however the number of chilling hours reported for Whalley and Campbell River, 10 and 17 weeks respectively, suggest that global warming will adversely affect Douglas-fir in the lower mainland and on Vancouver Island perhaps as far north as Comox.

The above discussion is concerned with long term effects. Of more immediate concern is the probably effect of increased winter temperatures upon the viability of planting stock. The majority of the nurseries in Oregon and Washington (and northern California) which grow Douglas-fir seedlings are located in relatively warm areas in winter. If the predicted temperature trends do, in fact, occur the incidence of temperatures greater than the mean is such that it is very probably we shall experience a winter with mean temperatures 5° C. greater than the present long term average before the year 2000. Should such an event occur, the majority of the stock in these nurseries will receive insufficient chilling and have, consequently, a very low survival potential.

A second major probable effect of global warming upon forest trees in western North America is described very elegantly by Cannell (1988). Working with data from weather stations maintained continuously over one hundred years in Scotland, he shows that, for species whose chilling requirements will continue to be satisfied by even the warmest predicted climates, i.e. lodgepole pine and white spruce in interior British Columbia, the date of mean bud break will occur at a lower mean temperature than is true presently. Accordingly, these species will be subject to a much greater risk of frost damage from late spring cold events.

Cannell, M. G. 1988 in press Climate Instability, Phenology and Potential Spring Frost Damage. IN Lavender, D. P. (compiler) Proceedings IUFRO Symposium Woody Plant Growth in a Changing Physical and Chemical Environment, U.B.C., July, 1987.

Lavender, D. P., R. K. Hermann & D. D. McCreary. 1986. Chilling requirements of Douglas-fir. IN Proceedings of the North American Forest Biology Workshop, 15-16 June, Oklahoma State University, Stillwater, Oklahoma.

Lavender, D. P. 1981. Environment and shoot growth of woody plants. Research Paper 45, Forest Research Laboratory, Oregon State University, Corvallis, Oregon 47 p.

TABLE 1

"CHILLING REQUIREMENTS" OF SOME FOREST TREE SPECIES

SPECIES	CHILLING REQUIREMENT (WEEKS)
DOUGLAS-FIR (<u>PSEUDOTSUGA MENZIESII</u>)	
VAR. <u>MENZIESII</u>)	13
VAR. <u>GLAUCA</u>)	17
WESTERN HEMLOCK (<u>TSUGA HETEROPHYLLA</u>)	4
WHITE SPRUCE (<u>PICEA GLAUCA</u>)	4 - 8
AMERICAN ELM (<u>ULMUS AMERICANA</u>)	9
LOBLOLLY PINE (<u>PINUS TAEDA</u>)	2 - 8
ENGELMANN SPRUCE (<u>PICEA ENGELMANNI</u>)	6 - 8
BREWER SPRUCE (<u>PICEA BREWERIANA</u>)	6 - 8
NORWAY SPRUCE (<u>PICEA ABIES</u>)	6 - 8
RED-OSIER DOGWOOD (<u>CORNUS SERICEA</u>)	3
LINDEN (<u>LILIA PLATYPHYLLOS</u>)	5 - 6
SCOTS PINE (<u>PINUS SYLVESTRIS</u>)	6
JAPANESE RED PINE (<u>PINUS DENSIFLORA</u>)	6
SWEETGUM (<u>LIQUIDAMBAR STYRACIFLUA</u>)	7 - 9

Draft Statement for Meeting on Climate Change in BC Forests
Oct 13, 1988

PALAEO ECOLOGICAL PERSPECTIVES ON MODERN CLIMATE CHANGE.
Ken Lertzman, Resource Ecology, UBC.

1. Introduction.

It is becoming clear that we are faced with changes in global climate that are unprecedented, certainly in the last 10,000 years, and perhaps substantially longer. The effects on natural ecosystems of all kinds, on forestry, on agriculture, and on human populations, will be widespread and profound. There are a variety of responses that need to be made; active intervention to reduce inputs of greenhouse gases to the atmosphere, pro-active changes in forest management and planning to minimize the effects of climate change, and research on the responses of plants to changes in climate from the physiological to the landscape levels. Here, I will focus on lessons from research on population and community responses to past climate change.

Throughout evolutionary time forests have been faced with changing climate, and the last 2 million years has been a time of particularly large and frequent changes. There is great potential for understanding how forests respond to changing climate by examination of the past. However, data on population and community level processes are not generally represented in the pollen record. The merging of population ecology and palaeo-ecology holds great promise, not only for theory, but in anticipating and mitigating responses to modern climate change.

2. Cypress Park Long-Term Forest Dynamics Project.

With Dr. Linda Brubaker of the University of Washington, I am in the preliminary stages of a research project investigating the population and community level processes of climate-driven changes in sub-alpine forest communities. For the past several years, I have been studying modern community change in an old-growth sub-alpine forest at Cypress Provincial Park. Dr. Brubaker and I have begun describing the history of this forest over the last 5,000 years based on pollen profiles from the soil within the stand. I will be developing a model of long-term climate driven change in this forest based on my own work, regional climate history, and on the pollen record. The goal of this project is to assess the extent to which our understanding of short term ecological processes, when driven with changing climate, can account for the long-term patterns found in the pollen record.

This project has several unique aspects. It is rare to be able to extract pollen profiles from forest soils, and this allows us to do reconstructions of stand development rather than charting landscape level changes. This is the first time the modelling approach that we are taking has been used for long-term modelling of climate driven change. Finally it is one of the first attempts to merge short-term ecological processes with long-term palaeo-ecological patterns in western North America..

2. General Conclusions About Long-Term Forest Dynamics and Climate Change.

What conclusions have come from palaeoecological research about the responses of forest communities to changing climate? How might these be useful in thinking about modern climate change?

1. Communities don't respond as communities. Individual species respond individualistically based on their autecologies and critical life history characters such as seed dispersal ability.
2. Because of this, forest communities as we see them today are relatively recent in origin and do not have a history of "integrity" in the face of changing climate.
3. The rates of movement of tree species distributions have generally on the order of 10-40 km/100 years. In a very few cases - such as white spruce moving into the Yukon 9,000 years ago - movement along migration fronts has been substantially faster. In general, the ability of tree distributions to equilibrate with climate is very much slower than the rate at which we can expect climate to change over the next 100 years.
4. It appears that natural barriers to dispersal such as large water bodies, mountains or other corridors of unsuitable habitat can substantially delay migration fronts (by >1000 years). The potential effects of this kind of factor are tremendous. For instance, the current impoverished state of tree species diversity in northern Europe can be traced to the barriers to species movement posed by the Alps during successive Pleistocene glaciations.
5. In BC, most major natural barriers to tree migration run north-south (e.g., the Coast Mountains). We can expect these to limit the natural responses of vegetation to any east-west shifts in climate. Human fragmentation of the landscape may also be important in posing barriers to adaptation in species distributions. Potentially, we can expect local extinctions.

6. The indirect effects of changed climate through changes in the frequency of fires or windstorms may be as great as the direct effects and may interact synergistically with them. The effects of changing disturbance regime may produce major changes in forested landscapes long before the effects of changing climate would do so directly.
7. Established populations of mature trees are able to persist under conditions in which new populations could not establish naturally, and in which it could be very difficult to establish new populations even under intensive management. Because of this we can anticipate increased regeneration problems, especially on marginal sites. In very dry areas, harvesting may convert sites irreversibly into non-forested status. In general, under a drying scenario, we can expect regeneration problems similar to those experienced in parts of Oregon and Washington.

8. In general, it is a good working hypothesis to expect that over the next 100 years climate change will exceed the ability of many forest communities to respond, and as a consequence we may see: local species extinctions, increased difficulty in post-harvesting regeneration, and a decline in the value of tools that depend on vegetation and soils being in equilibrium with climate (such the Biogeoclimatic ecosystem classification system and stand yield tables). We should be best able to minimize the effects of climate change in areas under intensive management, but much more of the province will be dependant on natural response mechanisms. To minimize the effects of changing climate in these areas, we need to act aggressively and pro-actively with management plans that maximize structural diversity on the landscape, increase the connectedness of forest units, and in general enhance ecosystem resilience.

3. Other Groups To Be Aware of.

There are active groups in Washington and Oregon who are concerned about these issues. Climate change problems do not stop at the border, and the coordination of responses to them shouldn't either.

University of Washington:
College of Forest Resources

Jerry Franklin: forest ecosystems, old-growth.

Linda Brubaker: palaeoecology, dendrochronology.

Jim Agee: fire ecology.

Botany

Matsuo Tsukada: palaeoecology, tree migrations.

Estella Leopold: palaeoecology, forest history.

Quaternary Research Center

A large group of people (including some of the above) with expertise in many issues relating to past climate change and responses to it.

Oregon State University/US Forest Service

Tom Spies

Fred Swanson

Mark Harmon

Arthur McKee

David Perry

The US Environmental Protection Agency has a Lab in Corvallis with active research on climate change and its effects in the American Pacific Northwest.

Climatic Change Information Meeting
13 October, 1988

Gordon A. McBean
Atmospheric Science Programme
Department of Geography
University of British Columbia

Background

The Department of Geography has a continuing interest in climatic change and its implications for the natural environment. Research studies have emphasized the energy and water balance of cities, mesoscale circulations of cities and coastal inlets, mountain and alpine hydrology and geomorphology, river flows and landslides. There has been a developing interest in land-surface processes, satellite remote sensing and geographic information systems. With the establishment of the Atmospheric Science Programme (jointly with the Department of Oceanography), there has been an extension into research on clouds and radiation, marine storms and the large-scale water cycle. In all these studies, there has been strong recognition of the importance of the social and economic impacts of climatic change.

A list of Department of Geography faculty, with interests in climatic change, is in Appendix A. For each faculty, there is a brief list of present research interests.

Current and Planned Research

Focus on the Water Cycle

Water is of major importance to many aspects of the B.C. economy (forestry, agriculture, tourism, hydroelectric power, fisheries, etc.). The water cycle, in this context, includes:

- precipitation and evaporation - the atmospheric component
- glaciers, runoff to rivers, lakes and directly to the oceans; water erosion, floods, etc.
- availability of water for forests, fish, the natural environment and for economic activities
- development of large-scale monitoring systems, using, for example, satellites and automatic stations
- socio-economic studies of the impact of changes in the water cycle, including historical data, models, and scenarios for future

Understanding the components of the water cycle is important to all aspects of climate. Our present climate is greatly influenced by the presence of water. Further, it is

anticipated that the climate will warm due to increased carbon dioxide and other radiatively-active gases in the atmosphere. Associated with the warming will be changes in the precipitation and evaporation patterns. The uncertainty for the predictions of changes in the water cycle is much larger than for temperature changes, yet the impacts could be much larger. The water cycle is a major aspect of the global system, which is particularly sensitive to global change.

1. Atmospheric Component

The water budget of the atmosphere is determined by the net rate of precipitation, evaporation and divergence of atmospheric transport. For the Northeast Pacific Ocean and the continental areas of Pacific Canada these terms are poorly known. For continental regions, the influences of topography add to the uncertainty of precipitation measurements, which are usually made at airport weather stations. Land-surface evaporation estimates, in mountainous regions, have a large uncertainty.

The atmospheric component of a study of the water cycle and its variability would focus on:

- evaporation and precipitation over the Northeast Pacific ocean
- water vapour transport over the B.C. coast
- precipitation processes in coastal regions including orographic enhancement
- evaporation and precipitation over the mountains and interior plateau

2. Hydrological and Geomorphological Component

Land surface runoff is the residual term of the water budget after evaporation and storage needs have been subtracted from precipitation inputs. Research into runoff variations in B.C. streams during the twentieth century has been complemented with studies of quaternary paleohydrology and methods of reconstructing past hydrologic environments. Fluctuations in sediment transport and water quality variations during the past thirty years have been investigated alongside Holocene lake and fiord sedimentation in the coast mountains. Research into meteorological antecedents to debris flows and groundwater fluctuations responsible for large scale earthflows have raised the question of more precise links between climate and geomorphic events. It may be possible to use geomorphic evidence to infer climate change in the past as well as to estimate geomorphic impacts of future climate change.

3. Satellite remote sensing of land-surface processes

The earth's terrestrial ecosystems are widely regarded as being an important component of the global climate system. The exchange of both energy and materials between the land surface and the atmosphere is influenced by the presence and nature of vegetation. Due to the extent of contemporary transformation of the earth's surface, greater understanding of the biotic influence on the climate is urgently required. In addition to biospheric parameters, satellite remote sensing may provide regional estimates of certain hydrologic and atmospheric parameters, such as evaporation and soil moisture and cloud cover.

The remote sensing component of the study of the water cycle and its variability would focus on (for Pacific Canada):

- temporal and spatial variability of satellite derived vegetation indices in relation to land-surface processes;
- determination of satellite derived biospheric parameters, e.g., vegetation cover, primary productivity, etc.;
- regional estimates of hydrological and atmospheric variables, such as, evaporation, soil moisture, cloud cover, and surface "skin" temperature.

4. Impacts of changes to the water cycle

4.1 Urbanization

Urbanization often results in radical change to surface water availability due to removal of natural vegetation, increase in impermeable cover, alteration of water routing and drainage, irrigation and combustion. One component of the research studies on changes in the water budget would be

- to develop and test models to simulate changes in surface evaporation and water availability from urban terrain; and
- to assess the impact of these changes on the heat balance and thermal climate of cities.

4.2 Land Use and Hydrology

Attempts to establish land-use effects on sediment yield and water quality have involved consideration of background biogeochemical cycling, quantitative land-use mapping, selection of appropriate water and sediment transport and attenuation models and determination of critical amounts of land-use change required for hydrological response. In the Queen Charlotte Fish-Forestry Interaction Program, it has been shown that the impacts of mass movement on forest sites and fish habitats under present hydrologic regimes are minimally affected by land

use, largely because of the high level of tectonic and structural instability. New strategies for fish and forest management in the light of future hydrologic change are needed.

Future changes of runoff magnitude and frequency could affect fish, forestry and tourism related economic activities.

Appendix A

Department of Geography faculty with interests in climatic change

Olav Slaymaker

Professor, mountain environments, alpine hydrology and geomorphology, man's impact on geomorphic and hydrological processes, Head of the Department

Philip Austin

Assistant Professor, clouds and radiation, impacts on climate system.

Michael Bovis

Associate Professor, largescale landslide phenomena in southwest B.C.

Michael Church

Associate Professor, river channel changes in B.C. and across Canada.

Brian Klinkenberg

Assistant Professor, quantitative methods, computer modelling and geographic information systems.

Gordon McBean

Professor, atmospheric boundary layer, marine storms, climate change and the water cycle, Chairman of the Atmospheric Science Programme.

Stephen Nikleva

Sessional Lecturer, marine storms, applied meteorology, fire weather meteorology.

Margaret North

Senior Instructor, vegetation change in the lower Fraser Valley

Tim Oke

Professor, urban climate and the energy and water balance of cities.

June Ryder

Adjunct Professor, quaternary geomorphology of B.C.

Douw Steyn

Associate Professor, boundary layer meteorology, air pollution meteorology and numerical mesoscale modelling.

Graham Thomas

Assistant Professor, land surface processes in global climate systems and modelling climatic impacts of land-use change.

Policy Analysis, Uncertainty, and the Effects of Climate Change on Forests

**by
Timothy L. McDaniels¹**

Introduction

The possible effects of changing climate on the Canadian forest resource involve enormous uncertainties; Canadian forest managers concerned about climate change would thus benefit from careful policy analysis that reflects these uncertainties (Pollard, 1987; Schelling, 1984). This brief paper has been prepared to articulate thoughts arising at a one-day workshop on climate change and forestry at the University of British Columbia in October, 1988. The following discussion is not intended as a critique of any specific papers presented at the conference; rather, the comments are intended to stimulate thinking about research priorities in this complex area. In particular, the intent is to articulate a need for greater emphasis on policy analysis and treatment of uncertainty when structuring research activities.

Bad Science and Good Policy Analysis

Scientists are primarily trained as disciplinary specialists. Thus, they tend to focus on in-depth understanding of narrow problems and often pay less attention to an integrated perspective linking many successive elements of an overall scientific or technological problem. This narrow perspective can be seen in much of the research being pursued on climate change and forestry today. The papers at this workshop have revealed relatively little attention to overall integrated views of the potential problems climate change could pose for forest management, and even less attention to the policy and economic components of the problem.

¹ Visiting Assistant Professor, Huxley College of Environmental Studies, Western Washington University and Principal, McDaniels Research Ltd., Vancouver, BC, Canada.

Another way that scientists could be characterized is that they often are hesitant to speculate about problems; they have been trained to seek proof of hypotheses before articulating their views. While this process leads to good science, it also leads to poor policy analysis: if society must wait until all the facts are in before attempting to make decisions about problems, opportunities to make effective change are inevitably missed. Granger Morgan, Head of Engineering and Public Policy at Carnegie Mellon University has argued forcefully that scientists need to pay closer attention to the policy side of problems, and be willing to speculate about the uncertainties in the difficult questions they face. It is only through this type of speculation and the process of using expert judgements, rather than proven facts, that society has the opportunity to take timely action regarding major environmental problems such as climate change or acid rain (Morgan, 1978). The purpose here is not to say that scientific research on climate change and forestry is unnecessary. Rather, the purpose is to argue that in addition to scientific research, we need a process of articulating alternative views regarding climate change and its implications for forest management, even before all the evidence is in.²

Explicit Recognition of Uncertainty

A corollary to the points above is that we should be hesitant in accepting any specific scenario regarding the effects of climate change on forests. The truth is that no one knows for certain whether global climate change is occurring, and if it is, how it will affect the forests of British Columbia. Accepting any specific scenario on climate change is akin to ignoring uncertainties in this environmental process. The most informative way to approach the problem would be to consider a number of scenarios regarding climate change, articulate the key uncertainties the scenarios are intended to reflect, and scrutinize available models to see how well they reflect these uncertainties.

To start, researchers should examine attempts to model uncertainty in other aspects of atmospheric processes, for example, the effects of sulphur air pollution on human health. Again, work by Morgan and his colleagues is instructive; their 1984 paper on the human health effects of sulphur air pollution has been referred

² Brewer (1986) discusses "policy exercises" as a means for articulating informed scenarios for complex problems such as climate change and forests.

to as an archetype of how uncertainty should be addressed in complex atmospheric environmental problems (Morgan et al, 1984).

The Need for Policy Related Research

Most analysts would concur that Canadians are primarily concerned about the effects of climate change on forests because of the possible changes in human uses of forests, including harvests for commercial purposes as well as non-consumptive forest uses. Given that orientation, research on climate change and forestry be directed toward the objective of providing information regarding those kinds of changes. That is, researchers should strive to link their specific activities to the broader perspective of providing information regarding how forest management and the full range of forest resources could be affected by climate change. This perspective suggests that high level models are required that are linked to annual allowable forests.

The need for policy analysis and economic assessment in forest/climate research is underscored by looking at previous research efforts regarding forests and air pollution, particularly acid rain. The US Environmental Protection Agency's National Acid Precipitation Assessment Program (NAPAP) activities concentrated its forestry modelling research largely on small area forest stand growth simulators such as the FORET model (Shugart and West, 1977). Because of the small area treated in the model (a 1/12 ha circular plot), its results were not directly usable to estimate the economic implications of acid deposition on forests. The lesson is that the links to forest-level policy decisions, particularly annual harvest levels, are crucial for doing policy and economic oriented analyses.

Forest level models could also be used to provide insights regarding policy options open to forest managers in order to respond to problems of climate change and forestry. However, it is worth stressing that the policy options available to Canada in this context seem to be relatively narrow. On its own, Canada cannot address the problem of global climate change. Rather, changes in the patterns of energy use, land management, and other key factors will be required on an international scale (World Resources Institute, 1988). In that case, the options open to Canadian forest managers are limited to those activities that can manage global climate change better, given that it is occurring (Winget, 1987). These options include the following general areas:

- (1) changes in harvest regimes
- (2) changes in reforestation practices
- (3) changes in general land use activities.

Running across these options are two basic questions: what can we do to provide more flexibility in terms of opportunities to respond to the effects of climate change on forests? Are we undertaking the appropriate reforestation activities given the possibility of climate change and forests?

Neither of these questions can be answered with any certainty. The key point is simply that in a problem that involves so much uncertainty, a generic response is to maintain as much flexibility and diversity as possible in how we undertake forest management and forest harvests. This point suggests more attention should be paid to preserving the genetic information embodied in established ecosystems and old growth forests as a practical tool for responding to the uncertainties inherent in future forest land patterns. A second point would be that we should maintain as much flexibility as possible in reforestation activities. One possibility would be to undertake practices such as growing more than one species (including hardwoods and softwoods) on the same site, and avoiding high cost, intensive reforestation regimes that presume a particular species will be suited to that site 80 or 100 years from now.

Finally, policy research should be directed toward the issue of the value of specific kinds of information that could arise from new research regarding climate change. Value of information is a concept that has grown out of decision analysis (applied statistical decision theory) which is an applied approach for decision making under uncertainty. This formal framework can provide analytical insights regarding where the public should spend its research dollars in attempts to gain insights regarding the forest and climate change problem.

Dimensions of the Problem

Two final points suggest that the extent of changes in the forest base for a given scenario of climate change may be more drastic than is sometimes thought. One point is that climate stress is strongly linked to, and can exacerbate, other forest health problems. A tree stressed by inadequate moisture is more susceptible to

pests, air pollution, and disease. In addition, moisture problems lead to exacerbated fire problems; witness the experience in Yellowstone Park in 1988.

A second point is that managed forests typically are not diverse. Managers tend to rely on monoculture for relatively large areas, involving similar genetic stock, few species, and large areas of the same age class with uniform management practices. This lack of diversity suggests that such forests are not likely to be resilient in their responses to any sort of change, in particular such a profound change as climate (Holling, 1978). In addition, it is fair to say that management of these second growth forests may not respond well to climate change. Lack of knowledge of the effects of forest management practices has been pointed to as a major obstacle in the selection of forest management regimes (McDaniels Research Ltd., 1988). If knowledge is lacking under a state of a constant climate regime, then surely knowledge would be even more inadequate in the face of a changing climate.

References

- Brewer, G.D. (1986) "Methods for Synthesis: Policy Exercises", in Clark, W.C. and Munn, R.E. (eds) *Sustainable Development of the Biosphere*. Cambridge University Press, Cambridge.
- Holling, C.S. (ed) (1978) *Adaptive Environmental Impact Assessment*, Wiley, New York.
- McDaniels Research Ltd. (1988) "SDSS: A Decision Support System for Silviculture Investment Analysis", unpublished, Vancouver.
- Morgan, M.G. (1978) "Bad Science and Good Policy Analysis", *Science*, 201, 15 September, 971.
- Morgan, M.G et al (1984) :Technical Uncertainty in Quantitative Policy Analysis: A Sulphur Air Pollution Example", *Risk Analysis*, 4:3, 201-216.

Pollard, D.F.W. (1987) *Forestry and Climate Change: Facing Uncertainty*, E.B. Eddy Distinguished Lecture Series Monograph, University of Toronto Press, Toronto.

Schelling, T.C. (1983) "Climatic Change: Implications for Welfare and Policy" in *Changing Climate*, Report of the Carbon Dioxide Assessment Committee. National Academy Press, Washington, DC, 449-482.

Shugart, H.H. Jr. and West, D.C. (1977) "Development of an Appalachian Deciduous Forest Succession Model and Its Application to Assessment of the Impact of the Chestnut Blight", *Journal of Environmental Management*, 5, 161-179.

Winget, C.H. (1987) "Forest Management Strategies to Address Climate Change" Proc. First North American Conference on Preparing for Climate Change: A Cooperative Approach. Climate Institute, Washington, DC.

World Resources Institute (1988) *The State of The World*, WRI, Washington.

Jean-Pierre Savard
Biologist, Conservation and Protection
Canadian Wildlife Service
P.O. Box 340, Delta, B.C. V4K 3Y3

Some ideas and concerns on the effect of climate change on wildlife inhabiting the forest.

From a forest perspective

1. Given what we know now, how can we best protect ourselves against uncertainty.
2. Monoculture reforestation especially Douglas-fir should be reconsidered and mixed reforestation strategies examined.
3. Old growth and mature forests. Those are currently viewed as unrenueable resources which once depleted will not be seen again. Current strategies to set areas aside have to be reviewed in view of climate change. How much is needed? Where? What size of parcels?

Are enough parcels set aside to assure adequate genetic pools in view of impending climate changes?

Non-commercial species of today could become the species of the future.

4. Large clearcut areas leading to homogeneous stands along the coast could spell disaster under a changing climate becoming susceptible to fire and diseases.
5. Possible synergetic effects should be investigated thoroughly.

Wildlife could be affected by climate change in two ways

1. Climate will induce changes in forest composition and structure. Some wildlife species will suffer, others will benefit. This may cause imbalance in the community and increase disease and insect damage to the forest.
2. Climate changes will lead to new forest exploitation policies (i.e. shorter rotation times) which could affect negatively several wildlife species. Especially those associated with mature forest. Current strategies to set aside areas for wildlife and to manage stand exploitation to accommodate wildlife may not be adequate under the possible forecasted scenarios.
3. In the past little consideration has been given to wildlife in assessing optimal or sustainable yield exploitation strategies for forests. I hope that future policy changes will take wildlife into account as one part of the equation.
4. In view of impending changes it is important that policies be based on sound ecological principles and that all synergetics effects associated with forest exploitation be considered.

D.L.SPITTLEHOUSE

RESEARCH BRANCH, B.C. MINISTRY OF FORESTS, VICTORIA

Climate change could potentially have a drastic effect on forest growth and forest operations in B.C. However, four factors limit our ability to reliably determine the degree to which forestry will be affected. Most important is that the current climate prediction models give only a general idea of what changes may occur. The three most sophisticated models generally agree with respect to temperature distribution, but disagree with respect to rainfall and soil moisture distribution. Furthermore, their hydrology sub-models are weak, and the grid size of these models is such that large variations in terrain and vegetation must be combined into one unit. Consequently, predictions are for areas of much greater size than the area of a management unit.

The above situation is not something the forest community can address directly. However, the other three factors relate to areas in which we can be effective. Of major concern is our limited knowledge about the response of vegetation to climate. This information is required if we wish to predict the response of the forest to future climates, e.g. what trees will grow, their productivity, the response of competing vegetation, pests and diseases and the non-fibre uses such as wildlife, fish and domestic water resources. Linked to this is the third of the four factors, that is, we are uncertain as to what management related questions should be asked so as to manage for the effects of climate change. Finally, there is a need for funding to address the specific problem of climate change and forestry. We cannot redirect present funding, new money must be obtained.

The B.C. Ministry of Forests has much offer to address the second and third factors outlined above. Although much of the work that has been done by the Ministry of Forests is directed toward the management of the forest under present conditions, the work is relevant to managing forests in B.C. a changed climate. A major thrust of the Ministry has been the development and implementation of the Ecological Classification Programme for the management of forest lands. Although the present maps and reports describe vegetation under 'present' climatic conditions, the classification scheme is based on the relationships between the vegetation and the climate (macro and local) and the site (geology and geomorphology). Consequently, the information could be used as a first approximation assessing what species of vegetation may grow under the new climatic regime with the same site physical conditions.

More detailed interpretations of climate change scenarios require an understanding of the physiological response of the tree to the climate and site conditions. Such relationships are being elucidated as part of the Ministry's reforestation research programme. Similarly, the response of trees and sites to a large array of site preparation treatments is being determined under many climate and site regimes and will contribute to our understanding of these responses in terms of the physical processes involved

One important aspect of my research programme has been the development of computer models and other procedures to assess how weather and climate affect the soil moisture and thermal regimes, and thus the survival and growth of seedlings and trees. These process-oriented, short time step (1 day) models are, in my opinion, the type of model we will need for detailed assessment of how climate change may affect the growth of our forests. They may be simplified for certain management applications.

Our collection and studies of the genetics of trees from many areas will allow us to better understand the climatic range of species. It may also allow for the selection of variants that will tolerate a changing climate.

The Ministry will continue with its current research programme relating various aspects of forestry to weather and climate. Such information will allow us to better manage the forest under future as well as present climatic regimes. However, we require new funding if we wish to adequately address climate change and determine what management questions to ask in the framework of climate change. We cannot afford to address these questions by re-allocating present resources.

In conclusion, there are many aspects of forest science that need to be brought to bear on the issue of climate change. We all have a part to play. However, our efforts and the priority for funding should be considered in light of the fact that if the worse case predictions of climate warming come true, finding new food growing areas and relocating populations displaced by flooding of coastal land will be of much greater social and political importance than obtaining maximum productivity from the forest.

(Item for Proceedings of UBC Workshop on Climatic Change - Oct. 13/88)

Ecological Laws: A Framework for Speculation on the
Effects of Climatic Change

G.F. Weetman
Department of Forest Science
University of B.C.

Predictions of major changes in world temperature and moisture regimes invites speculation on how these changes will influence local and regional terrestrial and aquatic ecosystems.

There is a danger that speculation will concentrate primarily on economic crops and resource values. Since climatic change can be expected to fundamentally change ecosystem functioning and productivity, it is constructive to look for an expression of the fundamental ecological laws that control organism growth and development.

Pierre Dansereau (1962), a famous Canadian forest ecologist, made a collection of 26 such fundamental ecological laws (see below).

These are grouped under laws of ecotopic fitness (8), laws of community adjustment (5), laws of climatic response (6) and geographic laws of distribution (7).

A systematic speculation on how climatic change will influence long-lived forest ecosystems, within these groups of laws, suggests that influences will be very profound indeed!

This collection of laws is helpful in developing the forest research needs in assessing the effects of climatic change. There is clear need for careful study of the problem on a world-wide cooperative basis and to use paleoecological precedents.

Reference

Dansereau, P. 1962. Ecological tools and their use. Proceedings of the Lockwood Conference on Suburban Forest Ecology. Conn. Agric. Exp. Station. New Haven. Conn.

R.J. Williams
Waste Management Branch
British Columbia Ministry of Environment
810 Blanshard St.
Victoria, B.C.
V8V 1X5

The British Columbia Ministry of Environment planning and management over the next decade has an important mission: to encourage a sustainable environment, curb environmental degradation, and ensure that environmental management can meet the changing needs and priorities of the many users of our resources. Among the factors recognized as influencing the Ministry's Strategic Plan is global climatic change. If significant change in climate occurs, there will be an increased risk to public safety through rising ocean levels, greater frequency of floods and/or droughts, and loss of economic opportunities through effects on water supplies and consequently agriculture, fisheries, wildlife, and forestry. Social and technological adaptations to changing environmental conditions will increase demands for resource allocation and use. Without strict rules to govern this demand, further degradation of environmental resources and productivity will occur.

Of the nine external factors influencing the Ministry, a changing world environment is ranked as number three in priority. This demonstrates the seriousness with which the Ministry of Environment views this issue. Although global in scope, it is obvious that the solution to the problem lies at local, provincial, national and international levels, and the Ministry is actively examining ways to ameliorate the impacts.

**RECENT ACTIVITIES OF FORESTRY CANADA AND
PACIFIC FORESTRY CENTRE
IN CLIMATE CHANGE**

**D. A. Winston,
Program Director,
Pacific Forestry Centre**

During 1987-88, Forestry Canada has taken several initiatives with respect to the effects of climate change on the forestry sector.

In January 1988 we hosted a meeting with AES at Downsview, Ontario of 20 invited foresters, scientists and professors to examine the issue and potential impacts. Significant concerns were voiced by all regions of the country and this stimulated further activity and heightened awareness.

In June 1988 Dr. J. Maini, ADM Forestry Canada, presented a theme paper to the international conference on The Changing Atmosphere at Toronto. This meeting was chaired by Prime Minister Mulroney and by Mrs. Bruntland, the Prime Minister of Norway. The presentation gained national and international media attention and stimulated greatly increased awareness of the threat of global climate change to forestry in Canada. Dr. Maini predicted major shifts in forests throughout the world and he questioned if the Federal/Provincial development agreements (FRDA's) are adequately considering the issue in Canada.

In September 1988, senior scientists and managers of Forestry Canada met in Toronto to develop a strategic plan for attacking climate change. All of our regional centres and institutes have agreed that the issue is of major concern and requires attention. During the next few months specific action plans will be developed.

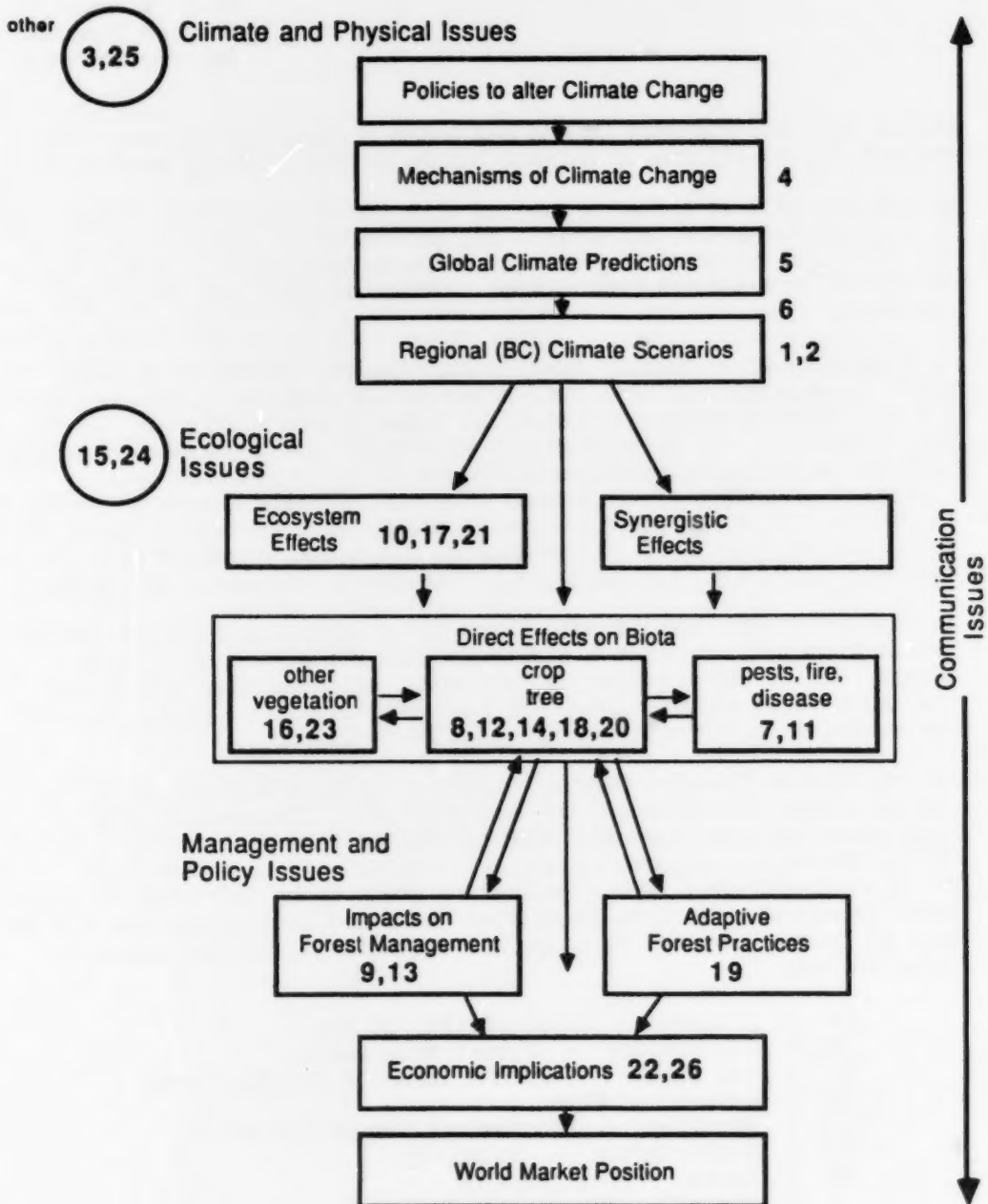
At the Pacific Forestry Centre, Victoria, we have already taken several steps. For example, we have held joint discussions with Environment Canada (AES) and BCMF to examine potential impacts, and to review the major subjects requiring attention. We have developed plans for a socio-economic impact evaluation study to be initiated in early 1989. In addition we have identified staff and data bases that may be able to become involved in cooperative studies with other agencies. These include:

- Dr. D. Pollard - Physiologist, policy
- Dr. R. Silversides - Forest meteorology
- Dr. A. Van Sickle - Forest Insect & Disease Survey
- Mr. B. Lawson - Fire
- Dr. J. Manville - Biochemical Stress Indicators
- Dr. E. Hetherington - Hydrology
- Dr. R. Smith - Soil Physics
- Dr. R. Prasad - Vegetation Ecology

During the next few months, PFC will develop a formal integrated Project involving several staff. We also will be continuing the Forestry Canada effort to publicize the Global Climate Change issue throughout Canada.

Issues Being Addressed by Researchers In British Columbia and Washington

based on Presentations made in Information Meeting
(numbers refer to topics on key)



Issues Being Addressed by Researchers in British Columbia and Washington

Key to Figure

This list is based on presentations at the Climatic Change Information Meeting at UBC October 13, 1988. The list should be reviewed, corrected, and supplemented by all participants. A distinction should be made between ongoing research and a research interest that may be pursued.

number	topic	research group
1.	Water cycle	UBC Geography
2.	Hydrology, Geomorphology	UBC Geography
3.	Satellite Remote Sensing, moisture data	UBC Geography
4.	Impacts; hydrology and land use	UBC Geography
5.	Biosphere Water Cycle, IGBP	ref. UBC Geography
6.	General Circulation Models, Gridded data bases	ref. Kirk Johnstone, AES
7.	Insect and disease surveys Fire research	CFS, Burnside
8.	Ecosystem study, Shawnigan Lake Provenance trials	CFS, Burnside
9.	Vegetation Management Options	CFS, Burnside
10.	Ecosystem Classification Program Forest Water Balance modelling Areal evapotranspiration Data logging in remote sites	
11.	Fire network / telemetry data	BC Min. Forests
12.	Plant physiology	BC Min. Forests
13.	Reforestation on various sites	BC Min. Forests
14.	Tree ring analysis (past climate)	FORINTEK
15.	Paleoecology, correlation to past climate	Provincial Museum
16.	Forest Regeneration: biochemistry, physiology, competition, etc.	UBC Forestry
17.	Climate change and species distribution	UBC Forestry
18.	Climate change and forest productivity	UBC Forestry
19.	Silvicultural systems to reduce risk	UBC Forestry
20.	Chilling requirements	UBC Forestry
21.	Framework for climate effects (ecological laws)	UBC Forestry
22.	Old growth and commodities landscape	U. Washington
23.	Botany related to climate change	U. Washington
24.	Lessons from paleoecology	U. Washington
25.	Climate Map of BC	Min. of Environment
26.	Policy and Economic Implications	T. McDaniels